The STAR Event Plane Detector

Strange Quark Matter

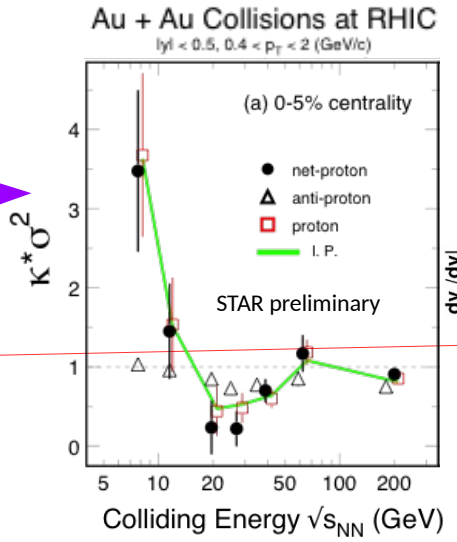
Jinlong Zhang For the STAR collaboration

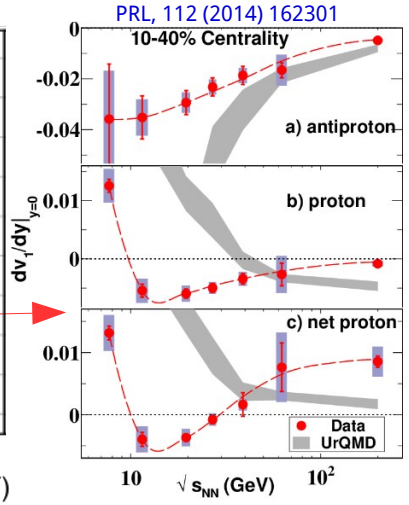
June 30,2016

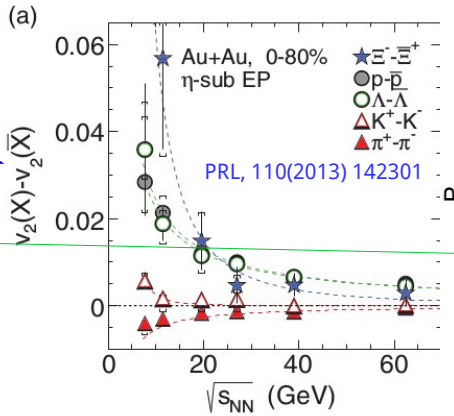
Highlights from the Beam Energy Scan (BES I)

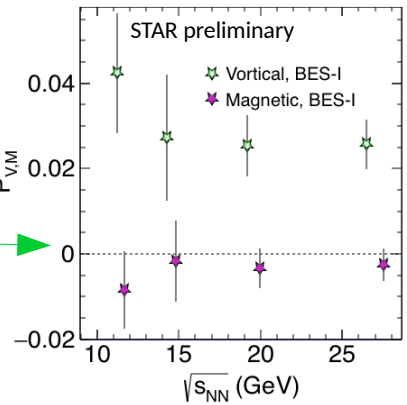
BES-I

Observable	Physics	Requirement
Net-proton higher moments	Critical point	Centrality
dv_1/dy of net protons	Phase transition	Event Plane
v_2 of identified particles	NCQ scaling, bulk properties (η/s) Chiral magnetic/vortical effects in strong interaction	Event Plane
Λ polarization	CVE	Event Plane



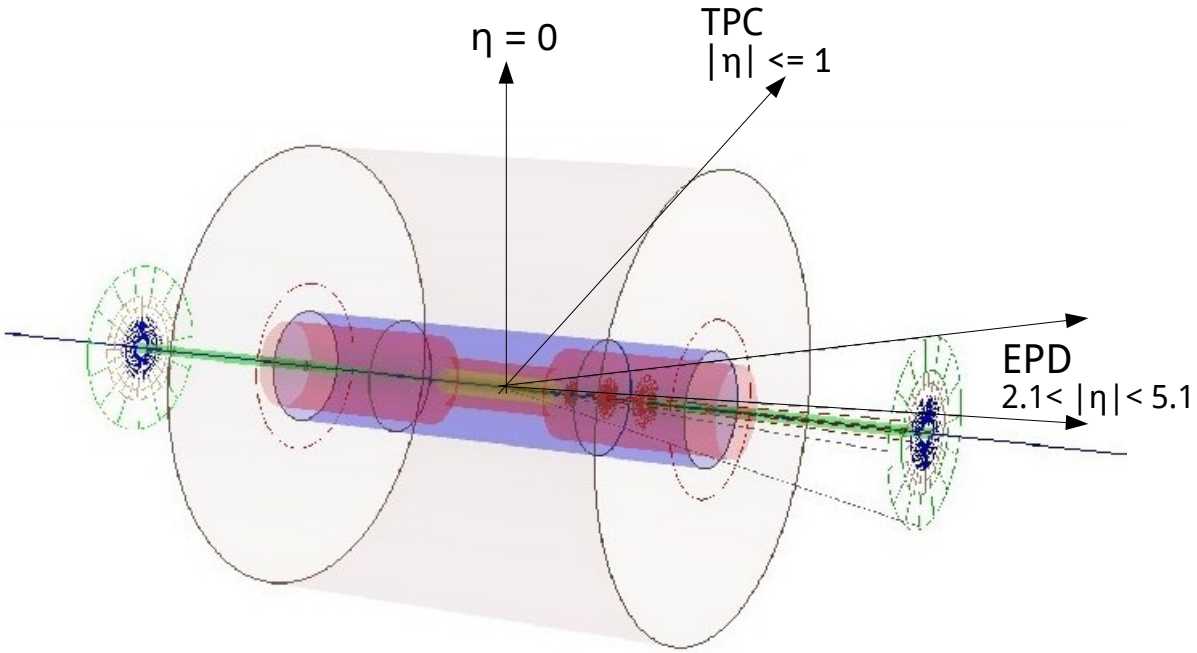


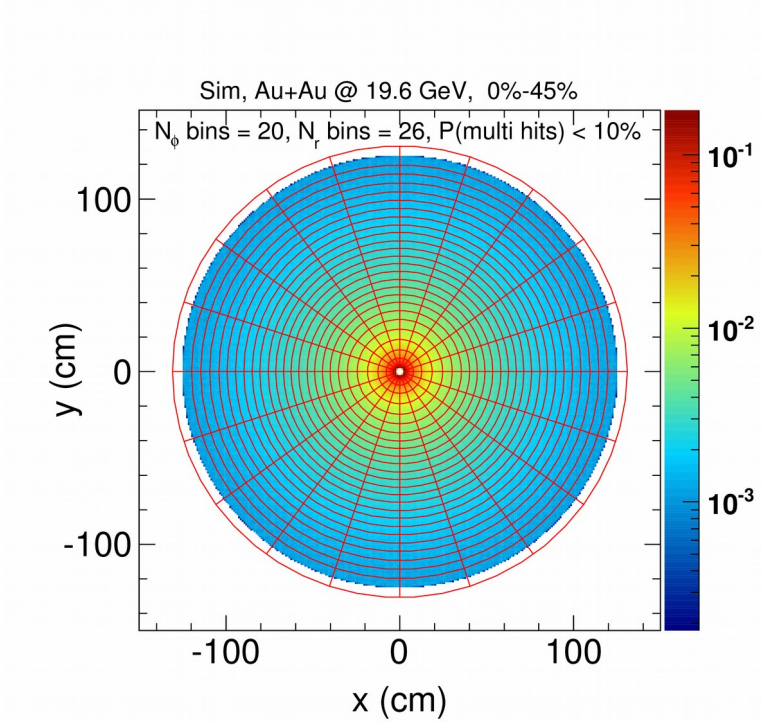




- BES II will improve previous physics measurements
  → better statistics and systematics
  → suppress auto-correlation to mid-rapidity
  → e.g. **E**vent **P**lane **D**etector

General Layout of the EPD

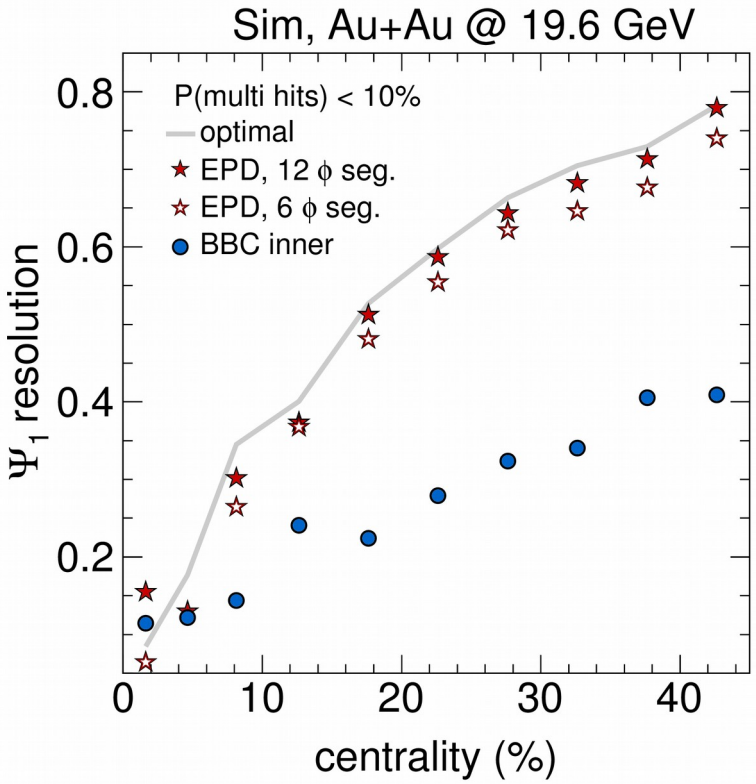


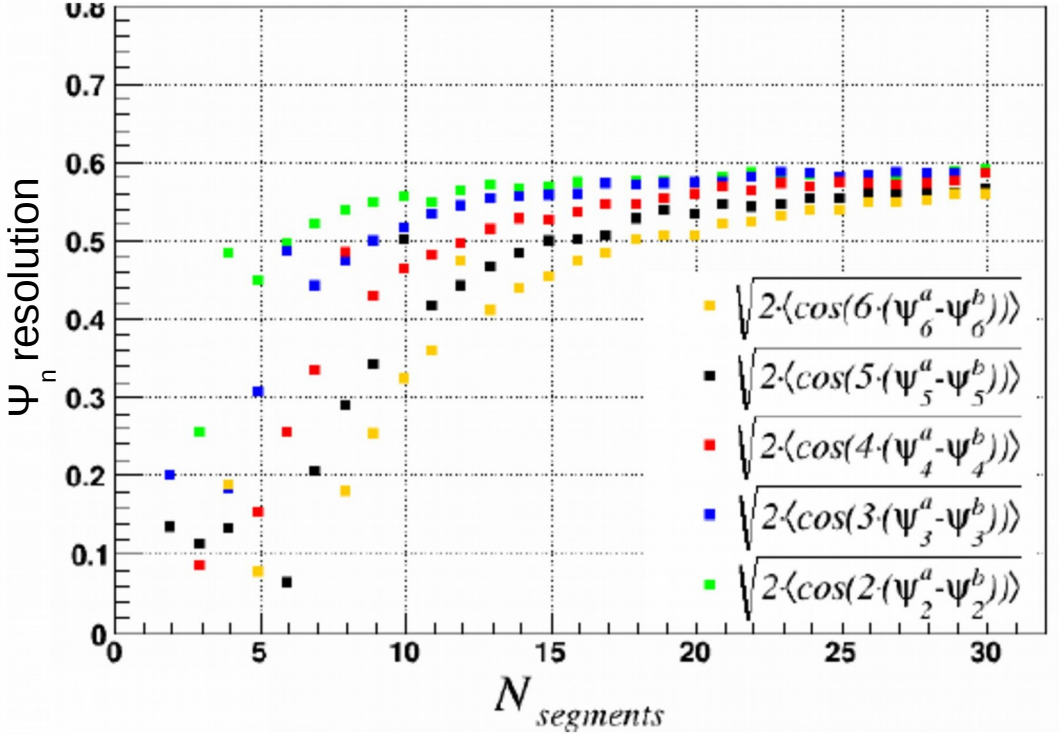


- Large forward eta coverage 2.1<|η|< 5.1 compared to TPC (|η|<1.0),
- Installed at z position +/- 375 cm
- High eta (radial) and azimuthal segmentation
- Good timing resolution (~ 1 ns)

- Radial and azimuthal segmentation optimized using measurements from PHOBOS and UrQMD simulations
- Final design layout: 24 azimuthal segments and 16 radial segments

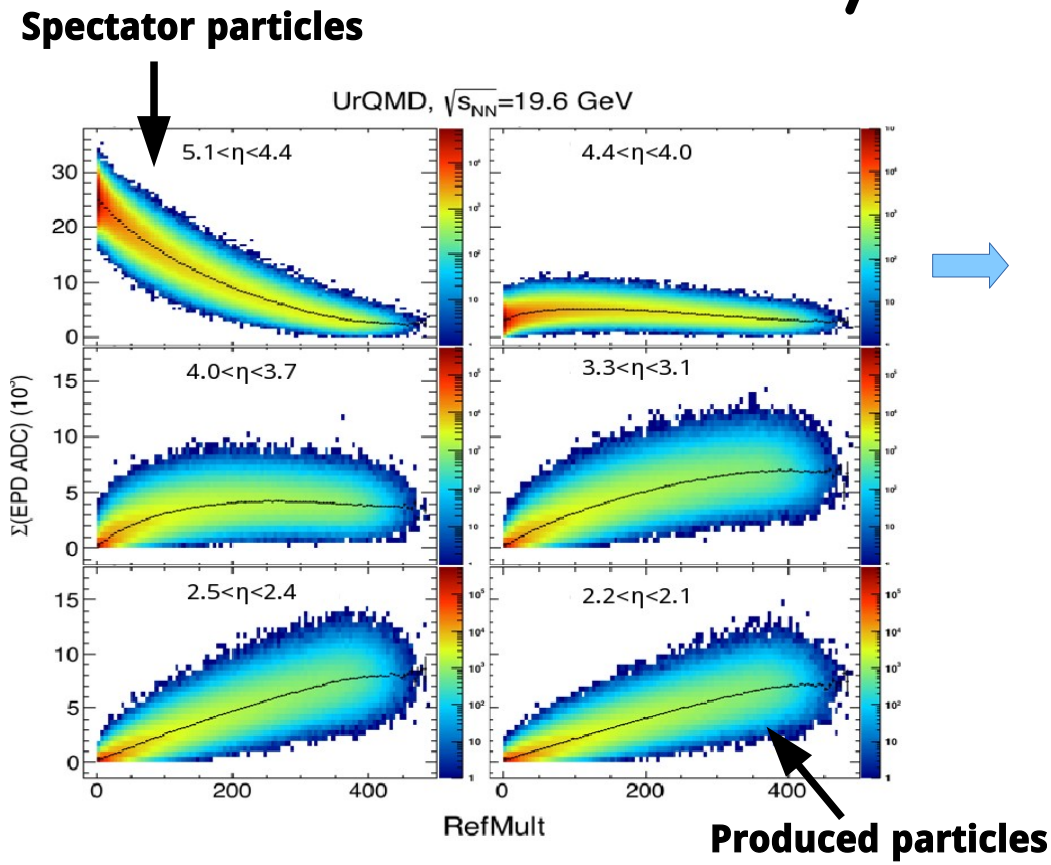
Event Plane Resolution



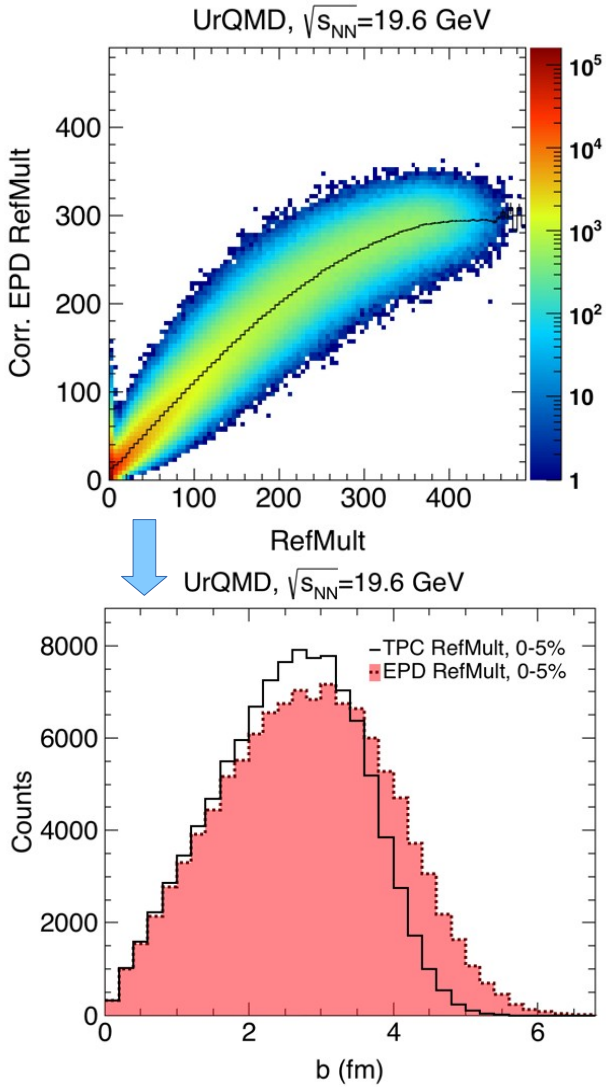


- EPD with 12 azimuthal segments is optimal for ψ_1 resolution
- Resolution is 2-4 times better than currently installed BBC detector
- 24 segments are needed for higher order (ψ_6) event plane harmonics

Centrality resolution

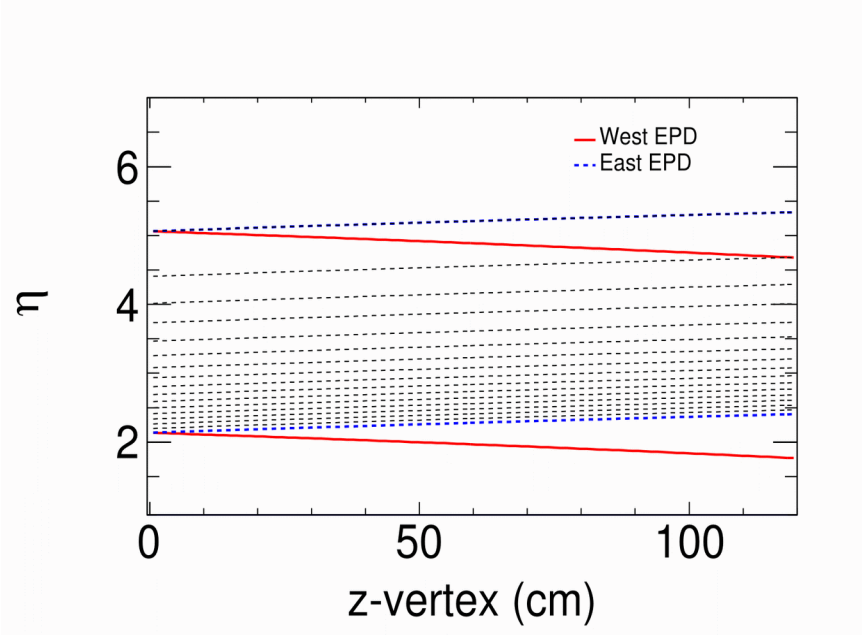


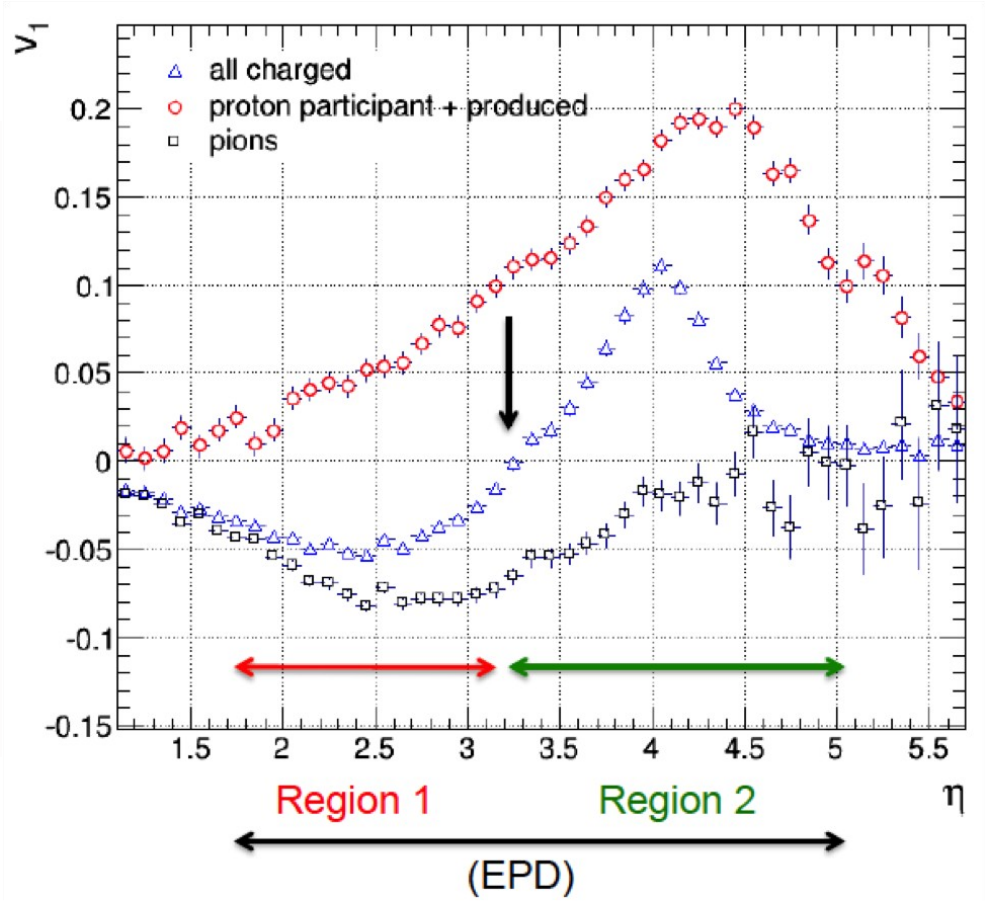
RefMult = number of particles ($|\eta| < 0.5$)



- ADC weighting used
- Spectator particles and produced particles can be combined to determine centrality, having a large radial segmentation
- Centrality from EPD will be used to reduce auto-correlations

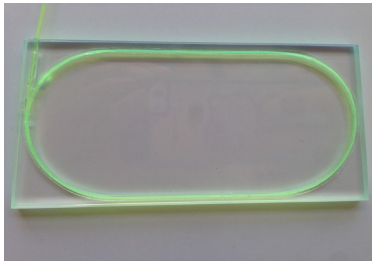
Use of high Radial Segmentation





- Large z-vertex distribution in BES-II, radial (η)-segmentation is needed to keep the same acceptance for every z-vertex
- Maximize v_1 signal by flipping signs at different η

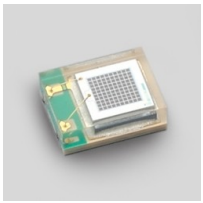
Technology



Eljen EJ-200 Scintillator
Eljen EJ-500 epoxy
Kurary Y-11 WLS fiber

- Wave Length Shifting (WLS) fibers exit side is polished, the embedded side is painted with reflective paint
- WLS fiber embedded and glued inside of 1.2cm scintillator
- WLS fiber triple layers: signal is 2 times larger than single layer
- Tyvek (1055B) as wrapping material

Perfectly suitable for timing resolution requirement and a large area detector



Silicon Photon Multiplier(SiPM)
1.3x1.3mm Hamamatsu
S13360-1325PE

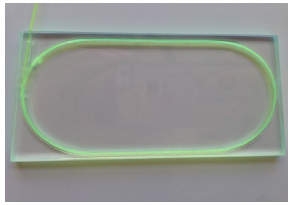
- Time of Flight coincidence resolving time ≤ 250 ps
- Gain on the order of 10^6
- Linear dependence of gain with voltage bias
- Total quantum efficiency ≥ 20% (wavelength dependent)
- Cost on the order of $20
- Not sensitive to magnetic fields
- SiPMs are small devices, allowing for compact designs

-->A good replacement for PMT in our case

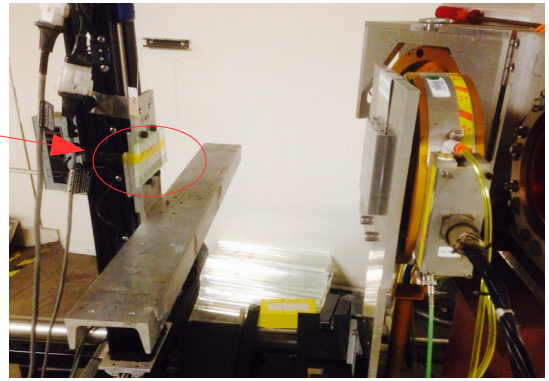
Perfectly suitable for 768 channels

but SiPMs+fibers+glue are sensitive to radiation

Radiation Hardness of Optical Components

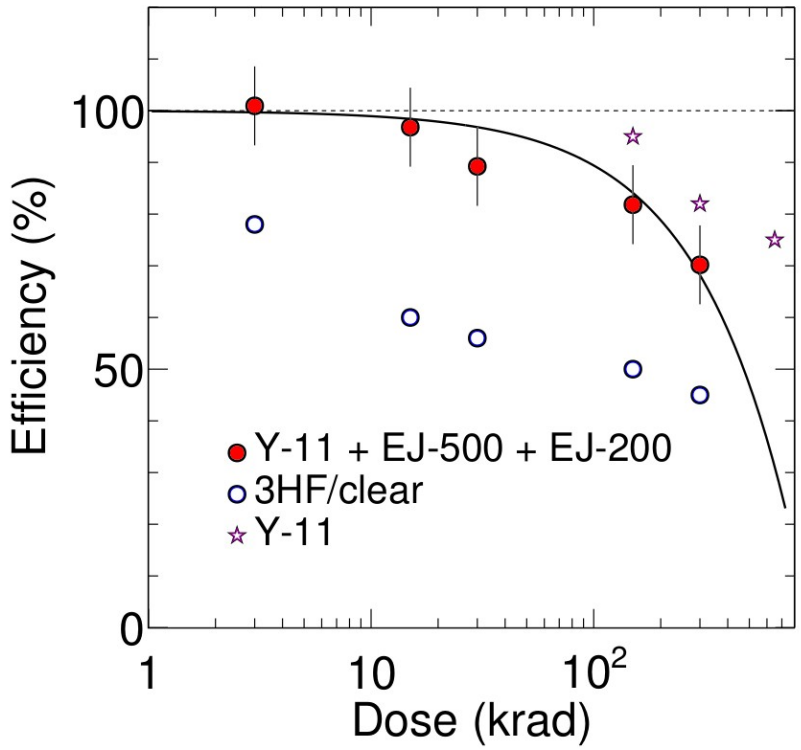


Eljen EJ-200 Scintillator
Eljen EJ-500 epoxy
Kuraray Y-11 WLS fiber



Irradiation data per tile

	Tile 1	Tile 2	Tile 3	Tile 4	Tile 5
Flux (ions/cm^{2}s)	2.5x10^8	2.5x10^8	2x10^8	6.5x10^7	5x10^7
Fluence (ions/cm^2)	1x10^{12}	5x10^{11}	1x10^{11}	5x10^{10}	1x10^{10}
Dose (kRad)	300	150	30	15	3
Efficiency (%)	70	82	89	97	100

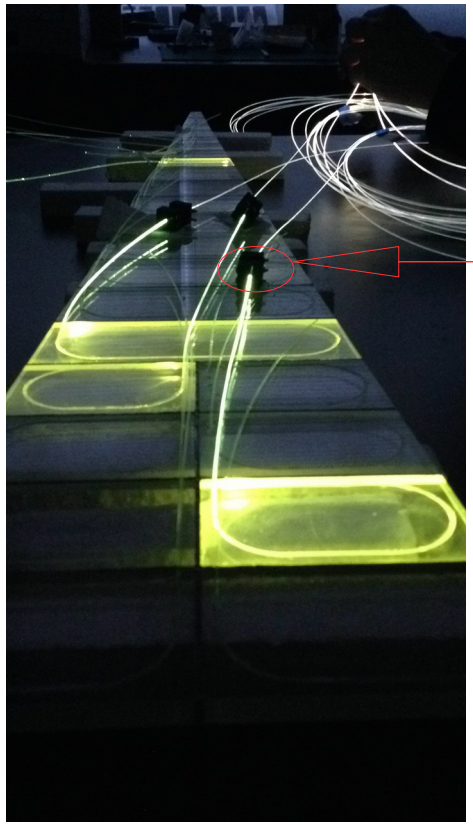


Measurement of the efficiency rate per dose of the assembled detector tiles compared with the reported efficiency rates of the Kuraray Y-11 WLS and 3HF clear optical fibers.

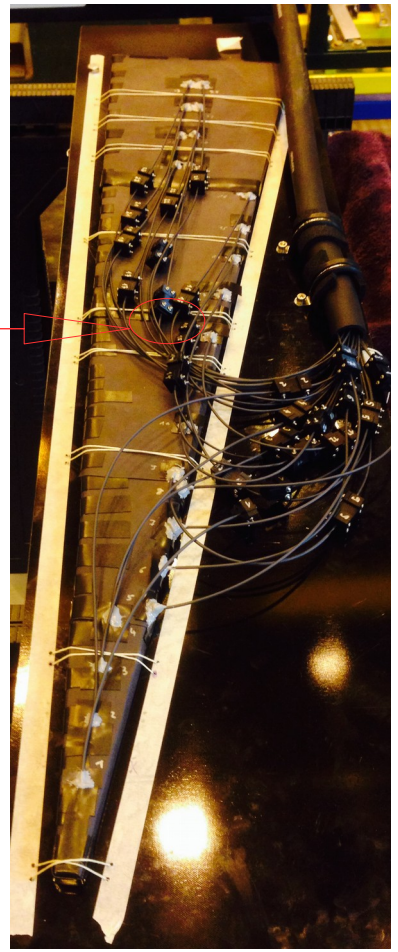
http://www2.ph.ed.ac.uk/~s0678696/neutron_damage.pdf
doi:10.1016/S0168-9002(98) 00281-2

- Five identical tiles irradiated with different doses
- Majority of the radiation damage to the tiles can be attributed to the WLS fibers, we consider epoxy is radiation hard

Prototype Assembly

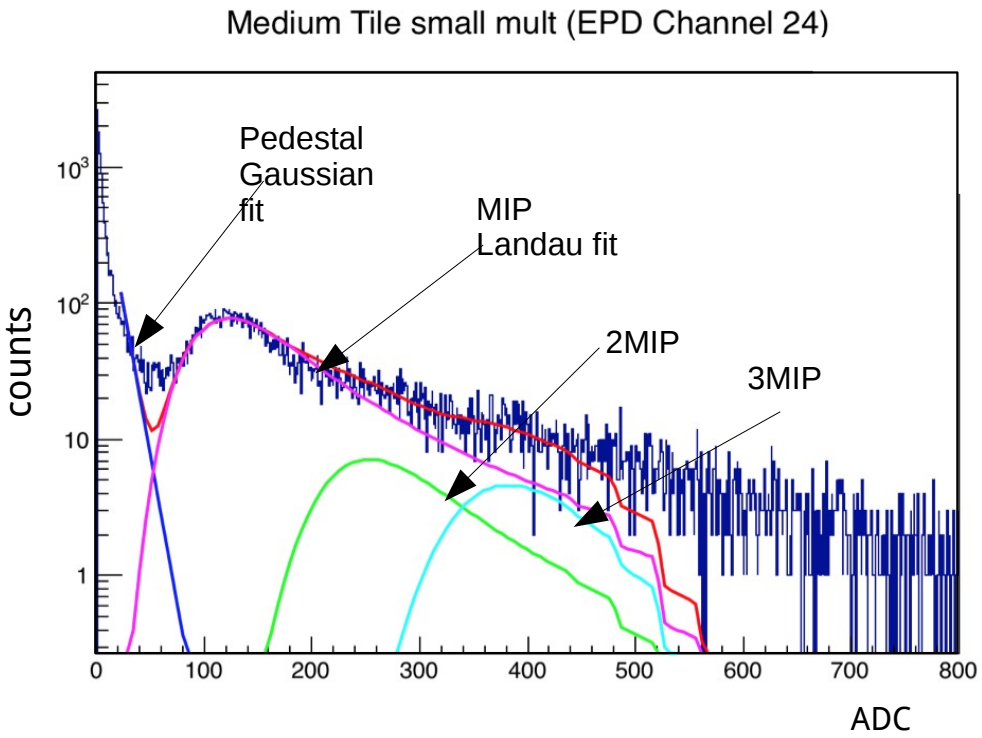


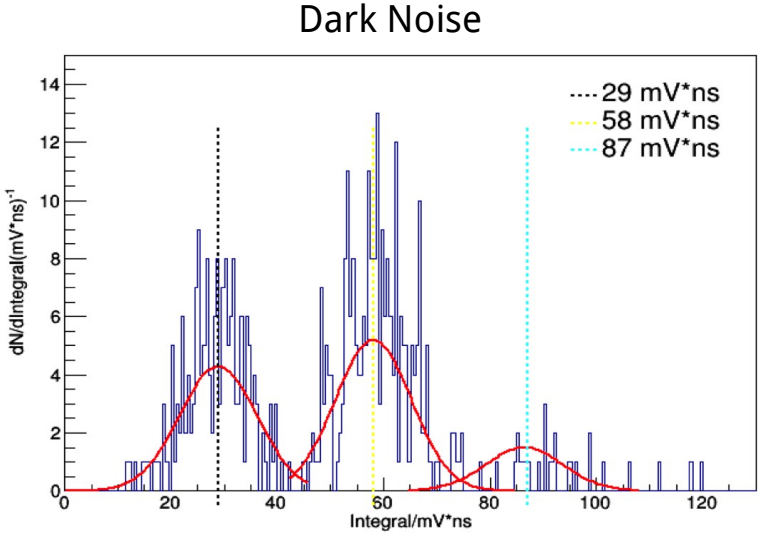
WLS fiber – clear fiber connector

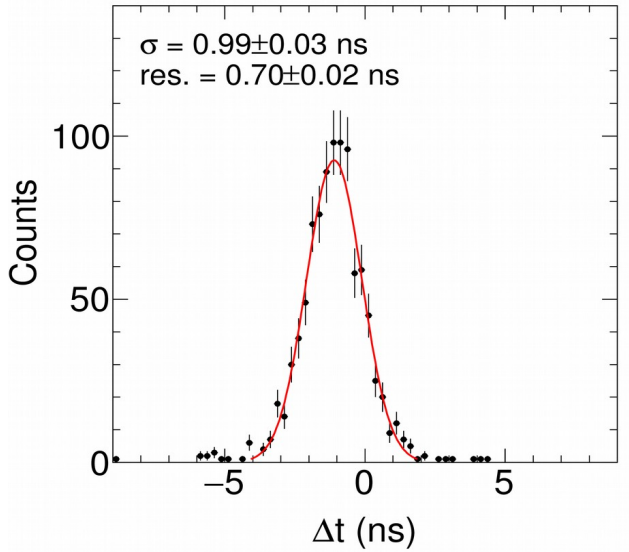


- The EPD prototype was installed at STAR and recorded data in 2016, $\sqrt{s_{NN}}$ = 200 GeV Au+Au
- WLS fibers are coupled to clear fibers (reduced attenuation length). All SiPMs are placed behind the magnet to protect them from radiation (~4 m fiber length)

Prototype Results and Dark Noise

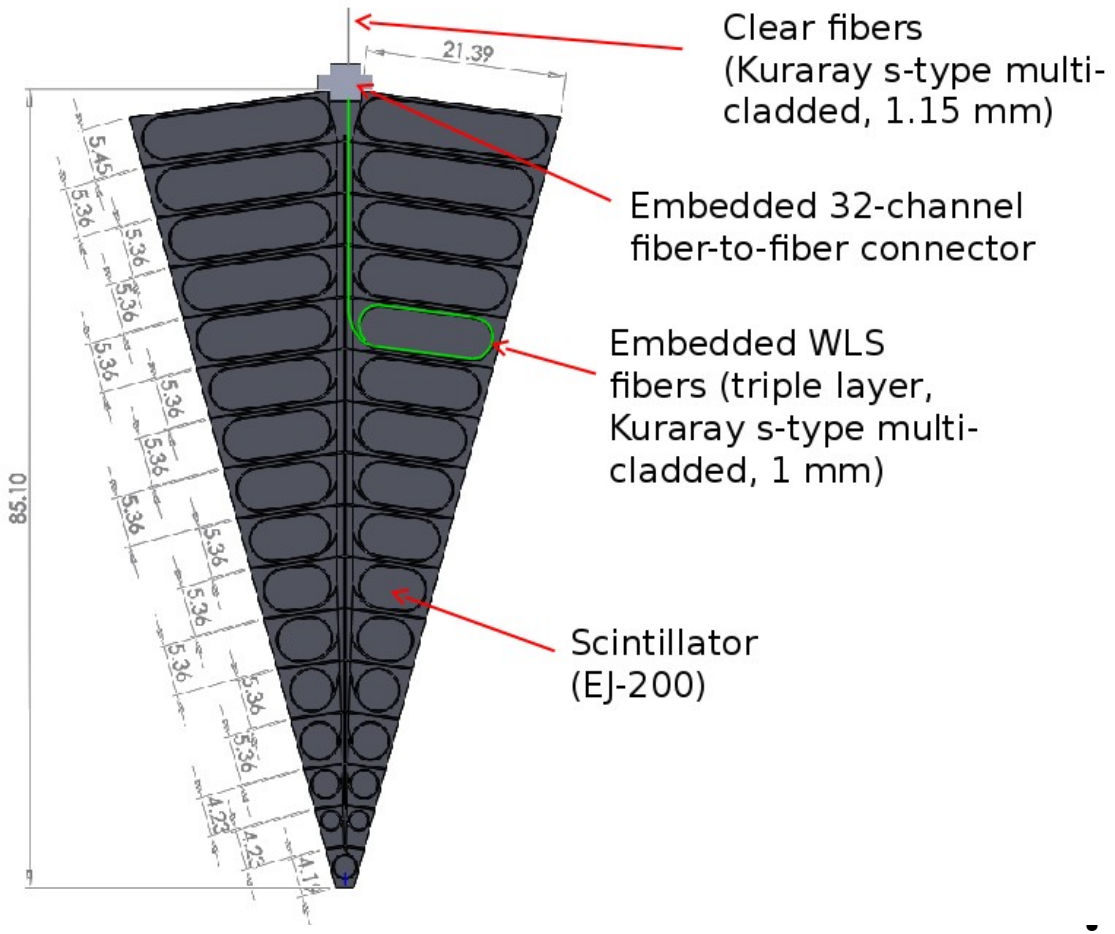


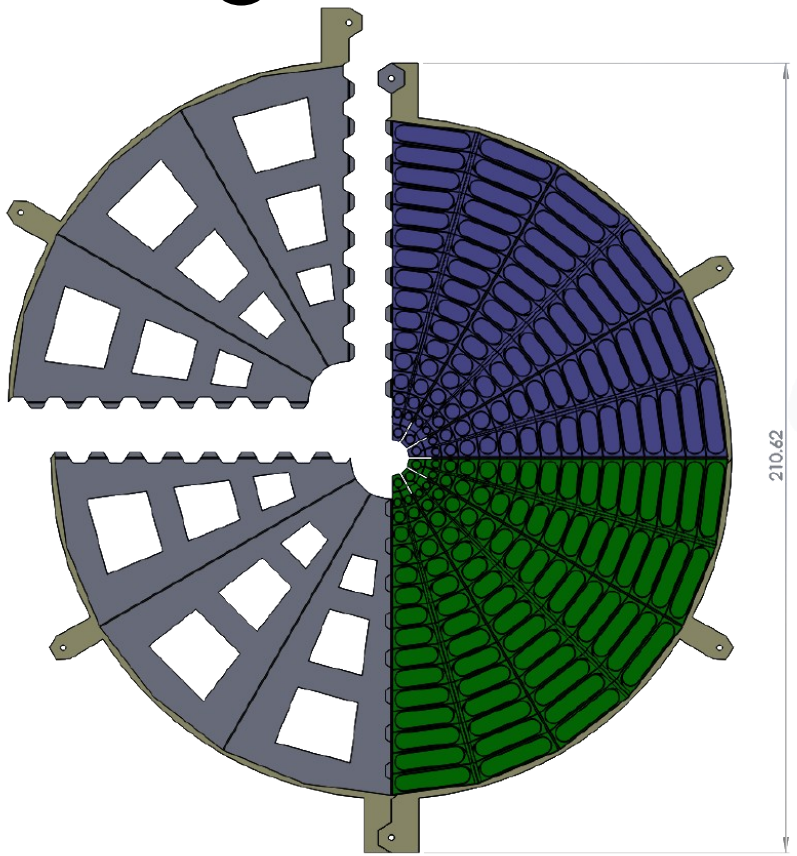




- EPD prototype single channel ADC spectrum with fit functions
- Consistent result between prototype and test branch setup: 250 photo-electron/MIP
- EPD timing resolution 0.7ns (old detector (BBC) ~1ns)

Final EPD Design



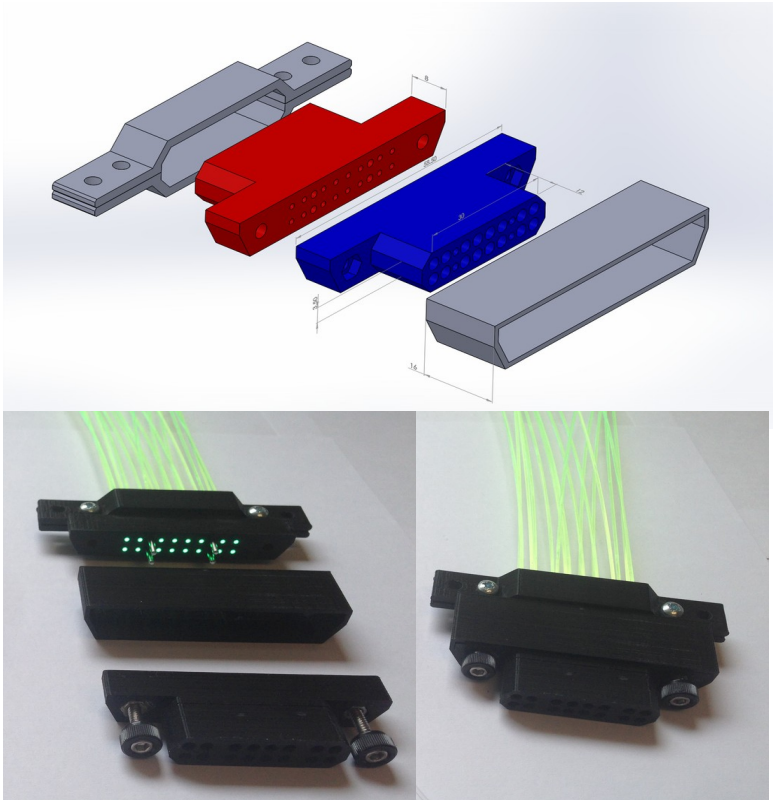


- Super sector consists of two sectors divided into 31 separate tiles
- Fibers will be routed in central grooves to outer edge connector

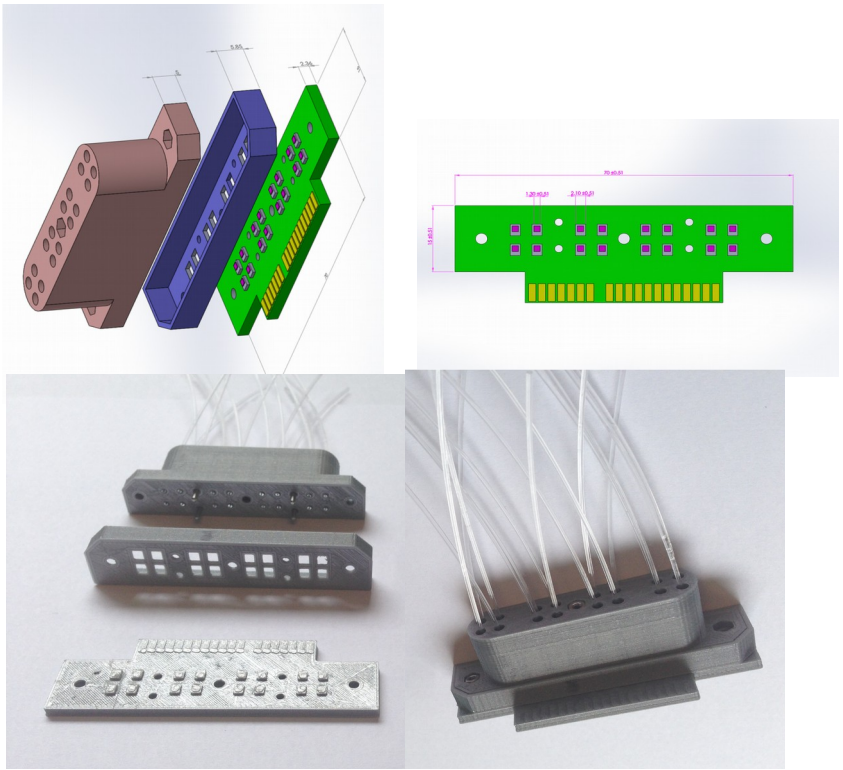
- Consist of four interlocking quadrants milled from 3/8 inch thick fiberglass-reinforced epoxy laminate
- Cutouts in frame to reduce weight

Connectors

Fiber-Fiber connector

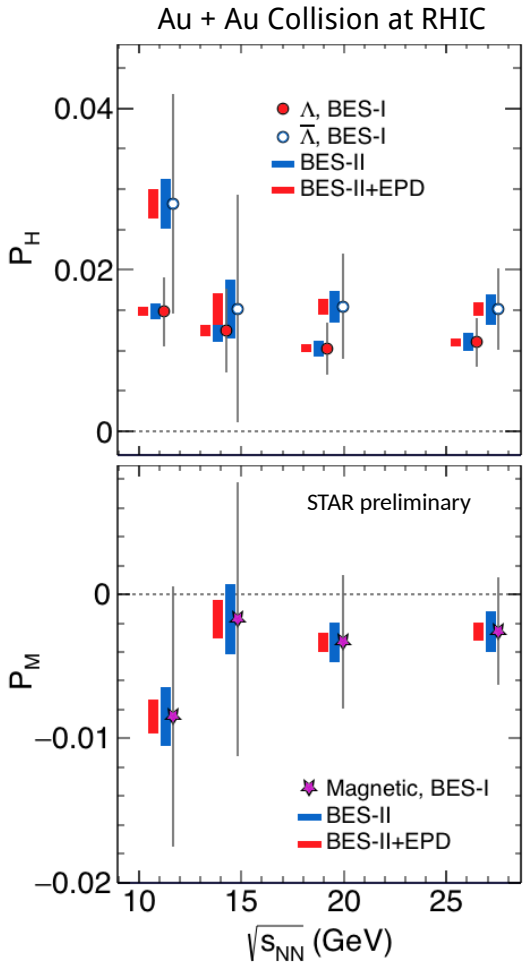


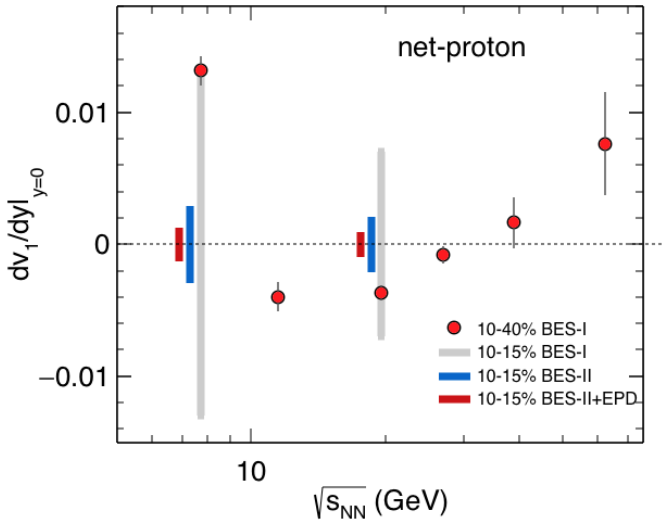
Fiber-SiPM connector



- 3D-printed connectors
- Final design 32 channel fiber-fiber connector and 16 channel fiber-SiPM connector

Projected Physics Performance





- EPD is going to reduce the auto-correlations to mid-rapidity measurements: net-protons, v_2,...
- The statistics (resolution) improvements are about 40%
  → e.g. needed to get a significant signal for P_M

Summary and Next Step

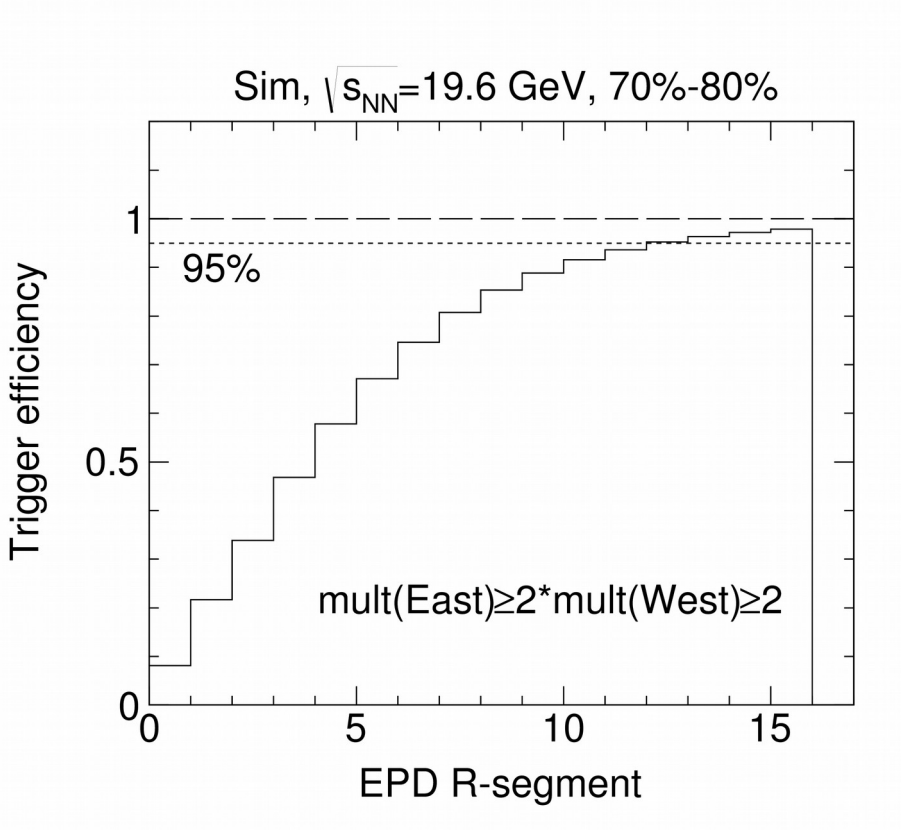
- EPD has high azumithal segmentation provide better event plane resolution
- High radial segmentation provide centrality independent with TPC
- R&D is complete and we have all the technical capabilities required to build the EPD
- The plan for 2017 operations is to commission the EPD:
  - 1/8th of the detector should be installed on one side of STAR
  - FEE will be re-designed from existing STAR read-out (FPS)
  - One super-sector is equipped with a new read-out board

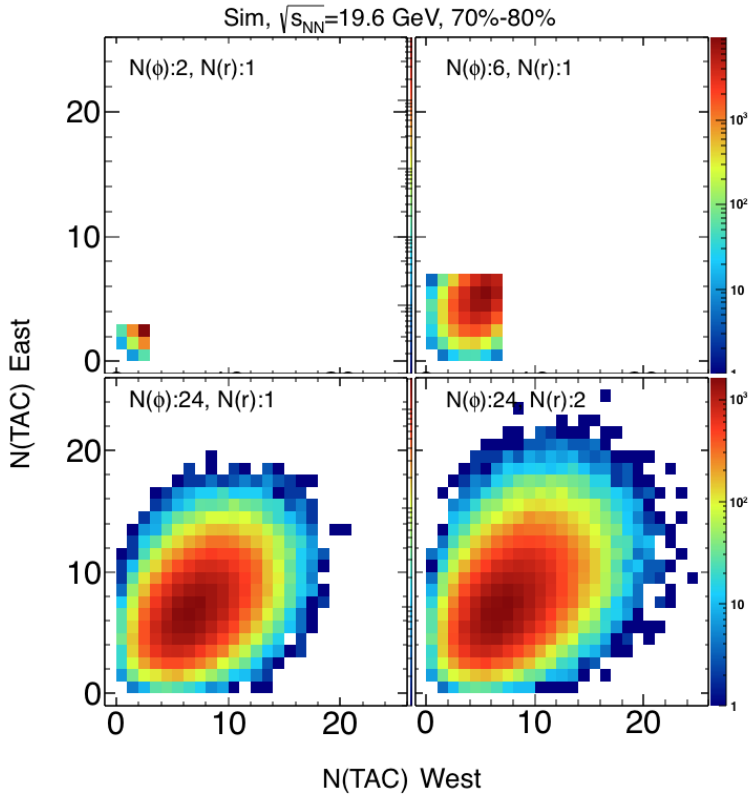
- 2018 full installation of all 24 super sectors

  → Data taking

Thank you!

Triggering





- EPD will replace BBC($3.3 < \eta < 5.0$ and timing resolution of 1 ns) as trigger for BES II.